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Polyimide Capsules Meet NIF Surface Finish Specification

Promising candidate materials for ignition capsules include polymers, such as polyimide, and beryllium. Capsules must have excellent sphericity and smoothness to meet the requirements for ignition. Recent improvements in the fabrication process of polyimide capsules have led to a significant reduction in the surface roughness, resulting in full-thickness ignition-quality capsules. The process involves first vapor depositing pyromellitic dianhydride (PMDA) and 4,4′oxydianiline (ODA), the monomeric components of Kapton™, on the mandrel in a bounce pan to produce a polyamic acid (PAA) coating (Fig. 1). When heated to 300ºC the PAA coating is converted to polyimide. However, the surface finish of the initially deposited PAA is quite rough (see Fig. 2, blue trace); thus before imidization, the capsules are vapor smoothed. In this process the capsule is levitated on a flow of N_2 that is nearly saturated with dimethyl sulfoxide (DMSO), an organic solvent in which the PAA is soluble. The vapors penetrate the coating, reducing its viscosity and allowing it to flow and thus smooth. After smoothing and while still levitated, the temperature of the N_2 flow can be increased to 300ºC to imidize the capsule. The details of these processes have been under intense study in the last year, and advances in understanding both the properties of the PAA-coated capsule[1] and the details of the smoothing process[2] have improved our overall process so that we are now producing ignition-quality capsules. First, we have learned that the uncured PAA coatings rapidly absorb ambient water vapor, resulting in the growth of undesirable surface features that cannot be removed by the smoothing process. We have eliminated this problem by limiting exposure to air. Second, we have optimized the smoothing process, studying carefully the factors that control the rate of sorption of the DMSO and the depth to which it penetrates. The result of these studies is that full-thickness NIF capsules that meet the NIF surface specification can now be produced. The red trace in Figure 2 shows the average power spectra of four smoothed polyimide capsules.

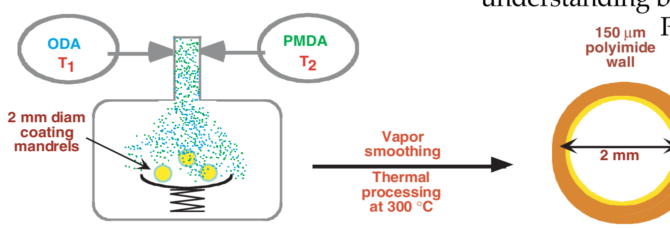

Figure 1. Vapor depositing PMDA and ODA to produce a PAA coating.

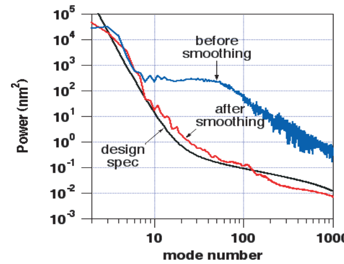

Figure 2. Smoothing dramatically reduces the roughness of polyimide capsules to the design specification.

1. S. Letts et al., to be published in *Fusion Science and Technology*, 2004.
2. M. Anthamatten, submitted for publication to *Langmuir*.

Target Designs with Graded Dopant in the Ablator

Recent designs of NIF ignition capsules, made of beryllium (Be) with copper (Cu) doped in a radially varying concentration through the capsule, tolerate surface roughness six times the best previous targets.

In early work on a marginal sub-scale NIF target, we saw improved performance when the Be ablator had a radially graded Cu dopant, instead of the usual uniform dopant.[1] Simulations this year show that there is a surprisingly significant advantage in performance when full-scale NIF targets use a similar graded dopant. The qualitative difference between these targets and uniformly doped designs is that the graded dopant tailors the density profile to reduce instability growth during the shell's acceleration. For targets driven at 250-eV radiation temperature, full-scale NIF capsules (300- to 700-kJ absorbed x-ray energy), which are direct scales of Dittrich's original 115-kJ absorbed-energy design, tolerate ablator roughness four to six times rougher than the best previous uniformly doped designs. At 300 eV and baseline scale, the advantage is equally spectacular: the targets can tolerate surface roughness six times the best previous targets, and more than 10 times rougher than a typical first generation NIF ignition target. Figure 1 shows the yield of this capsule versus surface roughness. Fabrication of Be capsules via sputter deposition has advanced sufficiently to be attractive, and graded doped Be should be a straightforward application of this technology. Currently measured surface roughness on sputtered Be targets, which would have been too rough for previous designs, appears to be acceptable for the graded doped designs.

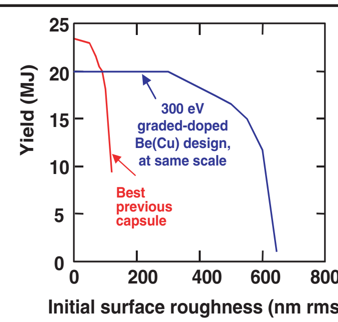

Figure 1. Yield versus ablator surface roughness for a new design using radially graded copper-doped Be, and for the most stable ablator capsule known previously at the same scale.

Since the implosion velocity and fuel mass are similar to previous designs, the sensitivity of the new designs to low modes is very similar to that of previous targets. It is likely that low-mode sensitivity can be improved by going to thinner shells, giving up somewhat on the spectacular stability at high modes.

1. Dittrich et al., "Reduced scale National Ignition Facility capsule design," *Phys. Plasmas* **5**, 3708 (1998).

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